Vermont Forest Health Monitoring Protocol

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About the Vermont Forest Health Monitoring Program

Website: http://www.uvm.edu/vmc/project/forest-health-monitoring

The Forest Health Monitoring Program was established in 1991 as a joint effort between the Vermont Department of Forests, Parks and Recreation (FPR) and the Vermont Monitoring Cooperative (VMC) (as of March 2017 renamed to **Forest Ecosystem Monitoring Cooperative** (FEMC)) to monitor the condition of a range of tree species in Vermont. Annual measurements of forest plots allow for a better understanding of trends in forest health, as well as potential drivers of decline. Plot design follows the structure set by the National Forest Health Monitoring Program with additional metrics added to reflect improvements in monitoring technologies and additions to monitoring objectives.

Monitoring was initiated in 1991 with 8 plots on the west slope of Mt. Mansfield, paired at 4 elevations. An additional 5 plots were added in the Lye Brook Wilderness Area in 1994 and 1995. These plots are located at similar elevations in each transect watershed, and where possible, are paired with two plots at each elevation. And in 1997, 6 additional plots were added on the east slope of Mt. Mansfield in pairs at 3 elevations. Initially, plots were visited every year, but beginning in 2008, a three-year rotation was established, moving between the east-side Mt. Mansfield plots in the first year, Lye Brook plots in the second year, and west-side Mt. Mansfield plots in the third year. In addition to the measurements described in this document, data has been collected at Mt. Mansfield and Lye Brook plots on down woody material, lichens and ozone bioindicator plants, but is not documented here.

In 2014, VMC and FPR mobilized additional resources to return to a yearly inventory and expand the network of plots across the state (

Figure *1*) in order to better represent the full range of forest types and ecological habitats across the state. In this way, the expanded plot network is designed to capture the condition of the larger forested ecosystem. To do this, only sites with existing or historical forest health inventories were considered in order to ensure that new permanent FHM plots included historical forest health data. By building off historical data, the data from these new plots can be tied back to earlier measurements, extending the monitoring record for the new plots. Specifically, the Forest Inventory and Analysis Phase 3 plots (http://www.fia.fs.fed.us/program-features/basic-forest-inventory/), Vermont Hardwood Health Surveys plots (http://www.uvm.edu/vmc/project/vermont-hardwood-tree-health-survey/), North American Maple Project plots (http://www.uvm.edu/vmc/project/forest-health-monitoring-north-american-maple), and Green Mountain National Forest Long-term Ecosystem Monitoring Program plots were targeted. In 2014, two plots were added to the network, in 2015, 20 more were added, and in 2016, 8 additional plots were added bringing the current network as of 2016 to 48 plots. Based on resources available and the number of plots, in 2017 plots will be added on a needs basis.

Vermont Monitoring Cooperative
Statewide Forest Health Monitoring Network
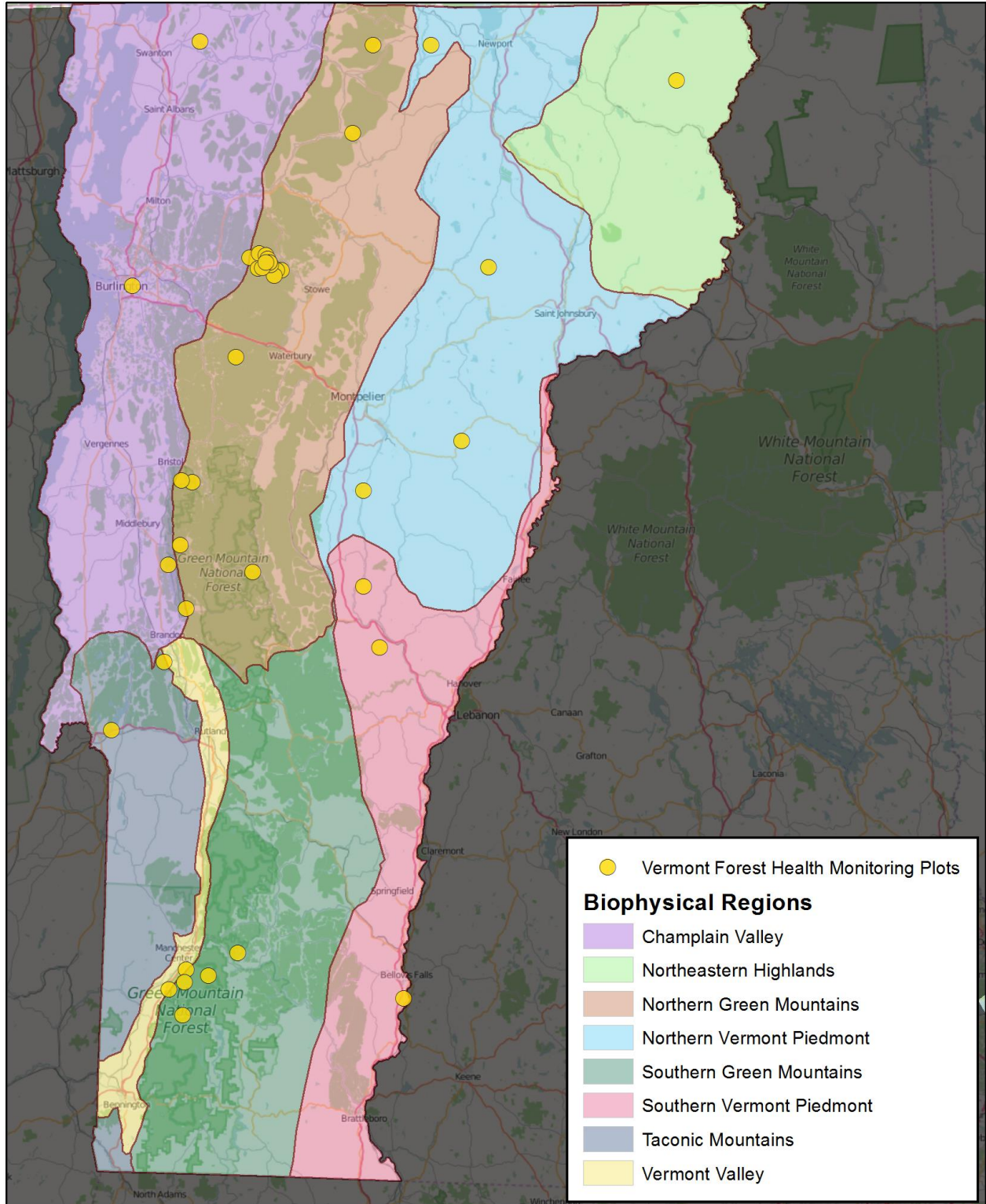
Figure 1.Map of current Forest Health Monitoring Plot locations, last updated September, 2015.

Plot Establishment

Plots are established and measured using an adaptation of the National Forest Health Monitoring (FHM) protocols[1]. Each plot contains 4 subplots, and each subplot contains 1 microplot (   ). All plots are oriented with Subplot 2 directly north of Subplot 1.
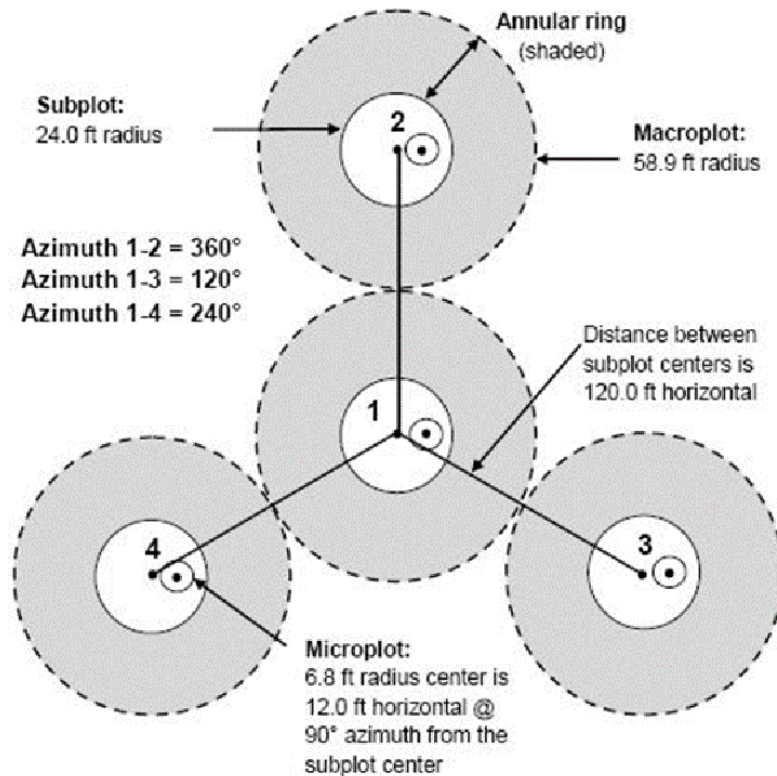
Subplot Establishment

Consistent and repeatable forest health measurements require permanent monuments to relocate plots annually. PVC pipe or wooden dowels at each subplot center are used and plot identification is written on them with permanent marker. Subplot 1 is established first, since it is also the plot center. The centers of subplots 2, 3 and 4 are 120 feet (36.58 m) from the subplot 1 center at 360°, 120° and 240° magnetic azimuth, respectively (   ). In federal wilderness areas, subplot centers are marked with wooden dowels driven down to the duff layer, and no information is written on the rods.

Coordinates of the center of each subplot are logged with a GPS. Instructions for this process using Trimble GeoExplorer are available in Appendix A. Each subplot is 24 ft. (7.32 m) in radius.

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[1] Forest Inventory and Analysis Phase 2 and 3 methods are online at http://www.fia.fs.fed.us/library/field-guides-methods-proc/index.php

Microplot Establishment

Each subplot has 1 microplot for assessment of regeneration, located 12 feet (3.66 m) east of the subplot center. Similar to subplot centers, microplot centers should also be monumented. We have found that smaller stakes (fiberglass or wooden dowel) are easily locatable while also appearing distinct from subplot center monuments. Each microplot is 6.8 ft. (2.07 m) in radius.
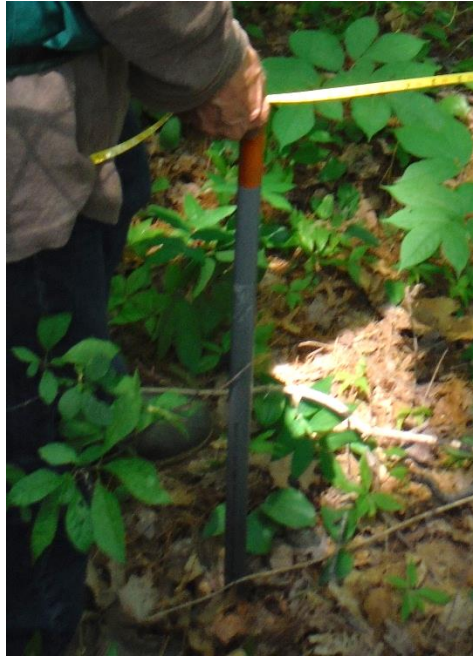
Figure 3. Standard subplot marker.

Annular Ring Area

This area is designed to allow for sampling that may alter plot integrity such as soil or lichen sampling, or tree coring. No formal markings nor annual measurements are collected in this area.

Plot Metrics Overview

Overview of Subplot Measurements

Before beginning data collection, you should consider ways you can maintain plot integrity such as storing your gear outside the subplot and marking the microplot to avoid unwarranted trampling.

All trees 5 in. (12.7 cm) and greater in diameter at breast height (DBH) in the subplot are measured. A tree is counted as "in" if the center of its pith is 24 ft. (7.32 m) or less from plot center. Trees are marked (either with paint, cold hardy flagging or tags) for future remeasurement. A unique number is assigned on the datasheet for future identification and tracking over time.

For each tree, the following are recorded:

Tree Location and Structure

‒ Unique tree number. When establishing a new plot, tree numbering begins with the first tree east of true north from the subplot center, and continues in a clockwise direction around the subplot. If two trees have the same azimuth, the tree that is closer to the center is given the lower number. Ingrowth trees are assigned a number during data entry to avoid assigning them existing tree numbers.
‒ Magnetic azimuth from plot center (we default to magnetic north to avoid errors in declination)
‒ Horizontal distance from the plot center to the pith of the tree (measured using a tape measure or hypsometer, see Appendix B for instructions on use of the hyposometer)
‒ Species (see Appendix C for species codes)
‒ Diameter at Breast Height (follow DBH protocol under "Tree Location and Structure Measurements ")
‒ Tree height and live crown ratio (total tree height, height to live top and height to live base; protocol under "Tree Location and Structure Measurements")

Tree Health

‒ Canopy position (FHM protocol, under "Tree Health Measurements")
‒ Crown vigor (NAMP protocol, under "Tree Health Measurements")
‒ Crown fine twig dieback (FHM protocol, under "Tree Health Measurements")
‒ Foliage transparency (FHM protocol, under "Tree Health Measurements")
‒ Defoliation (NAMP protocol, under "Tree Health Measurements")
‒ Foliage discoloration (VT FHM protocol, under "Tree Health Measurements")
‒ Special damage agents (VT FHM protocol, under "Tree Health Measurements")
‒ Canopy transparency by digital photography (VT FHM methods under "Photography Methods")

Subplot-Level Metrics

‒ Hemispherical photos over Subplot centers to quantify: Leaf area index, gap fraction and plot canopy transparency (see "Photography Methods")
‒ Non-native invasive plant abundance (VT NAMP protocol, under "Additional Subplot-Level Metrics")
‒ Browse presence/absence (see "Additional Subplot-Level Metrics")
‒ Basal area prism counts (see "Additional Subplot-Level Metrics")

Overview of Microplot Measurements

Measurements recorded on each microplot include:

Regeneration

- Seedling counts by species (see "Microplot Measurements")
- Sapling diameter (DBH), species, and azimuth and distance from microplot center (see "Microplot Measurements")

Hemispherical photos

- Photos taken over microplot center to quantify: Leaf area index, gap fraction and plot canopy transparency (see "Photography Methods")

Details of Measurements

Tree Location and Structure Measurements

Diameter Measurements

Tree diameter is measured at DBH (4.5 ft. / 1.37 m) on the uphill side of each tree 5 in. (12.7 cm) or greater in diameter.

- If there is a bulge at DBH, the tree is measured just above the bulge, where the bole returns to normal.
- Trees forked above 4.5 ft. (1.37 m) are considered as one tree (Figure).
- If the tree is forked 1 foot (0.3 m) or greater above ground or at 4.5 ft. (1.37 m), the diameter is measured up 3.5 ft. (1.52 m) from the pith joining forks (Figure 55).
- If the tree is forked below 1 foot, each fork is considered as a separate tree and measured at 4.5 ft. (1.37 m) (Figure 6).
- If a tree is dead, its DBH is recorded the first year it is found to be dead. After that, DBH is not measured again. DBH of dead and down trees are not recorded.
- Where allowed, trees are painted at 4.5 ft. (1.37 m) so that they can be measured in the exact same place each year.
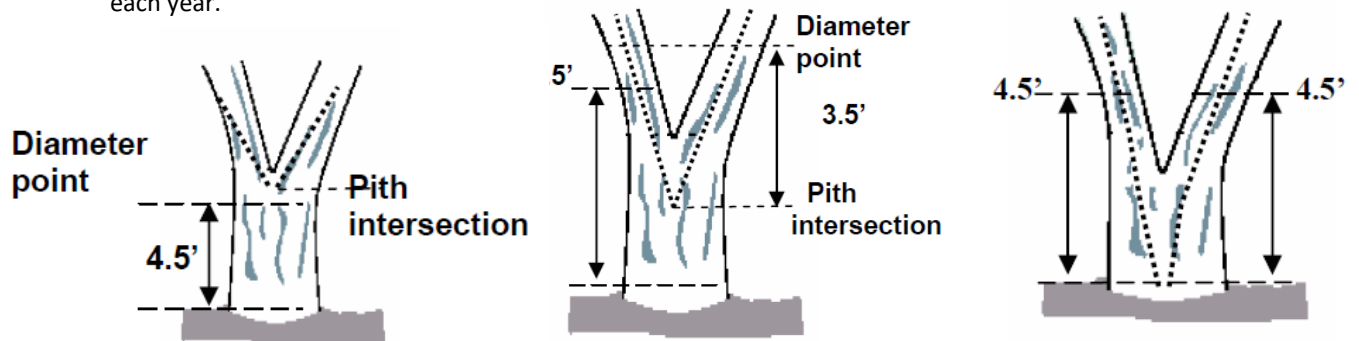
Figure 4. Tree forked above 4.5 feet.

Figure 5. Tree forked between 1 foot and 3.5 feet above ground.

Figure 6. Tree forked below 1 foot.
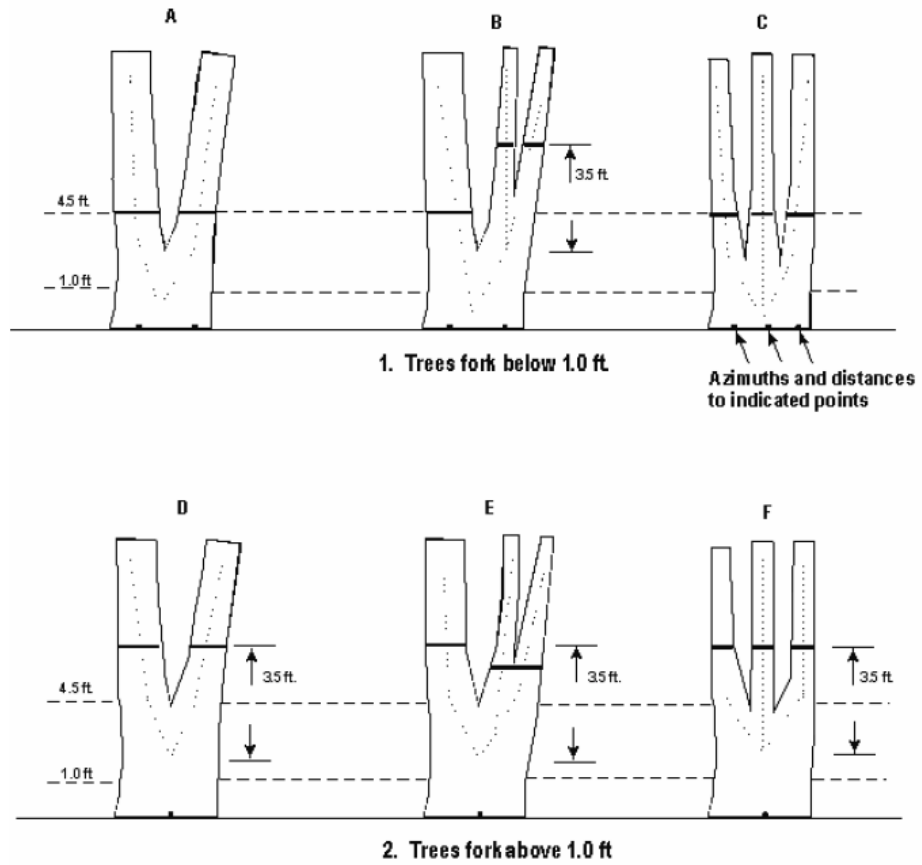
Figure 4. Summary of where to measure DBH, distance, and azimuth on forked trees.

Figure 5. Painting trees.

Height and Live Crown Ratio Measurements

The ideal location for accurately measuring tree heights is about 100 ft. (30.5 m) from the tree along the same elevation. Since this is not possible in dense forests, strive to find the furthest distance possible from the tree where both the top and live crown are visible. Tree height is measured using a clinometer or a hypsometer (See Appendix C. Using the Haglof Hypsometer for instructions on use of the Haglof hyposometer)

- **Total Tree Height** is the height to the highest point of the tree, either vegetation, twigs, or branches.
- **Height to Live Top** is the height to the highest point of vegetation on the tree.
- **Height to Crown Base** is the height to the lowest point of vegetation on the live crown

Figure 6. Measuring height with a Haglof hypsometer.

Determining Live Crown

The live crown base is an imaginary horizontal line drawn across the trunk from the bottom of the lowest live foliage of the "obvious live crown." The "obvious live crown" describes the continuous flow of foliage from the top of the crown extending downward to some point below which there is little to no foliage. Most crown branches/twigs are included, but epicormics, twig/sprigs, and straggler branches (more than 5 ft. (1.52 m) below the crown) that usually do not contribute much to the tree's growth are excluded. The base of the live branch/twig bearing the lowest foliage may be above or below this line.
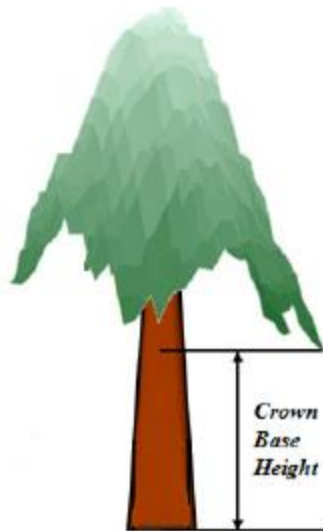
Figure 7. Determining the live crown base. The imaginary line is drawn at the base of live foliage. (Adapted from Jung et al. 2011)

Five Foot Rule

If any live branch is less than 5 feet (1.52 m) below this "obvious live crown" line, a new horizontal line is established as the base of the live crown. The new line is created at the base of live foliage on that branch. This evaluation is continued until no live branches greater than 1 inch (2.54 cm) in diameter at the point of attachment with the trunk are found within 5 feet (1.52 m) of the foliage of the lowest qualifying branch.

(Adapted from Randolph, 2010)

Figure 8. Determining new live crown base. Point of branch attachment is less than 5 ft. (1.52 m) from the base of the obvious live crown, so a new crown base must be determined. The new crown base is a horizontal line at the base of the live foliage on that branch. The new crown base is recorded as the crown base (Randolph, 2010).

Tree Health Measurements

Canopy Position (Crown Class)

Canopy position is the relationship of the tree relative to the other trees in the canopy. This is determined based on the amount of sunlight received on the various sides of the canopy and proximity to other trees (Tallent-Halsell, 1994). This is a subjective metric and is based on the comparison of the tree to the canopy surrounding it. Changes in canopy position changes are most likely following a stand disturbance.

Table 1. Canopy position codes and definitions (Tallent-Halsell, 1994).

Code	Definition
1	**Open Grown**. Trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.
2	**Dominant**. Trees with crown extending above the general level of the crown cover and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides.
3	**Codominant**. Trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated standards, codominant trees have small-sized crowns and are crowded on the sides.
4	**Intermediate**. These trees are shorter than dominant and codominants, but their crowns extend into the canopy of codominant and dominant trees. As a result, intermediates usually have small crowns and are very crowded from the sides.
5	**Overtopped**. Suppressed trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.
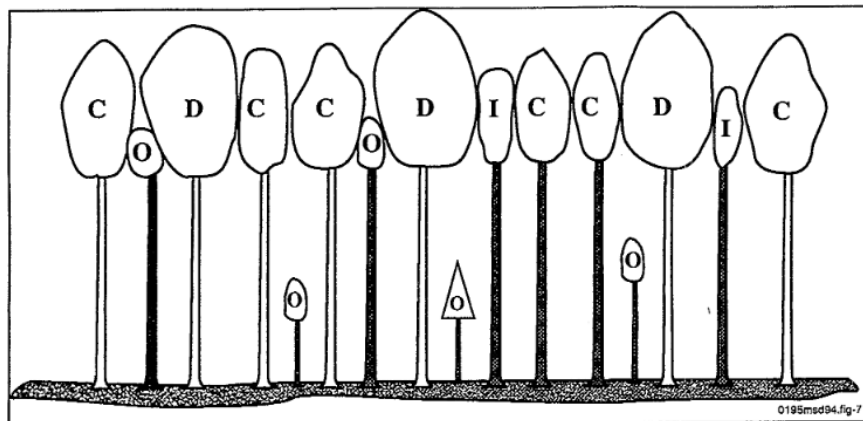
Figure 9. Relative crown positions of dominant (D), codominant (C), intermediate (I), and overtopped (O) trees (Tallent-Halsell, 1994).

Tree Vigor

Live tree vigor is a categorical assessment on a 1-to-4 scale that summarizes the overall "first impression" of the health of the tree (see Table 2). It is based on the sum total impact of a combination of stress characteristics, including branch mortality, dieback, and missing crown area (examples in Figure 10). Dead, cut and fallen trees are recorded as Vigor 5, 6, and 8, respectively.

Table 2. Tree vigor codes and definitions (Millers et al. 1991).

Code	Definition
1	**Healthy**; tree appears to be in reasonably good health; no major branch mortality; crown is reasonably normal; **less than 10** percent branch mortality or twig dieback.
2	**Light decline**; branch mortality, twig dieback present in **10 to 25 percent** of the crown; broken branches or crown area missing based on presence of old snags is less than 26 percent.
3	**Moderate decline**; branch mortality, twig dieback in **26 to 50 percent** of the crown; broken branches, or crown area missing based on presence of old snags is 50 percent or less.
4	**Severe decline**; branch mortality, twig dieback present in **more than 50 percent** of the crown, but foliage is still present to indicate the tree is alive; broken branches, or crown area missing based on presence of old snags is more than 50 percent.
5	**Dead, natural**; tree is dead, either standing or down; phloem under bark has brown streaks; few epicormic shoots may be present on the bole; no further entries needed.
6	**Dead**, **human caused**; tree removed; tree has been sawed or girdled by humans.
8	**Dead and down;** If a tree is found to be dead and down two years in a row, it is removed from the tree list.
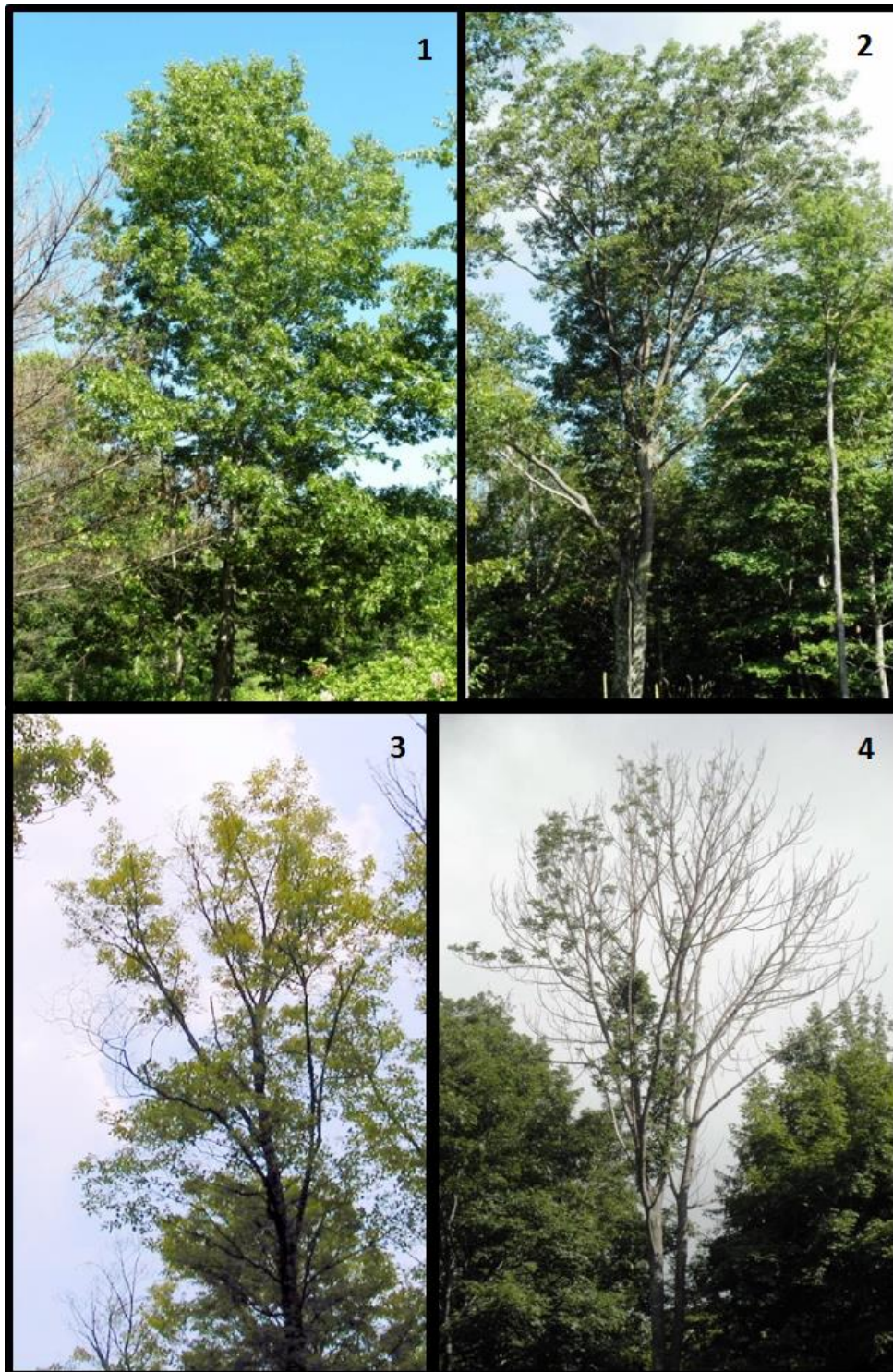
Figure 10. Trees with vigor 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right). Vigor ratings are located in top right corner of each photo.

Crown Fine Twig Dieback

Crown dieback reflects a tree's response to recent stress events. We estimate crown dieback as a percentage of the total live crown area (see "Tree Location and Structure Measurements"), that is occupied by fine twig dieback rounded up into 5% classes (if a tree has 1-5% dieback, it is rated as a 5, if a tree has 6-10% dieback it is rated as a 10, etc.)

To estimate the percent area occupied by dead twigs, it is helpful to project a two-dimensional outline around the **live crown** and denote the relative proportion occupied by fine twig dieback area. This can only be determined after a full examination of the tree from all sides. Because of the subjective nature of this assessment, it is imperative that 2 or more individuals assess fine twig dieback from different angles of the tree and then discuss their estimates. When two individuals disagree, they discuss the estimates and move around the tree to view it from different angles until an agreement can be reached. Because many tree species experience natural dieback (not stress related) of lower and interior limbs as trees mature, this metric only considers dieback of **upper and outer** branches where dieback is likely a result of stress and not simply natural pruning or self-shading.

(Adapted from Tallent-Halsell, 1994)
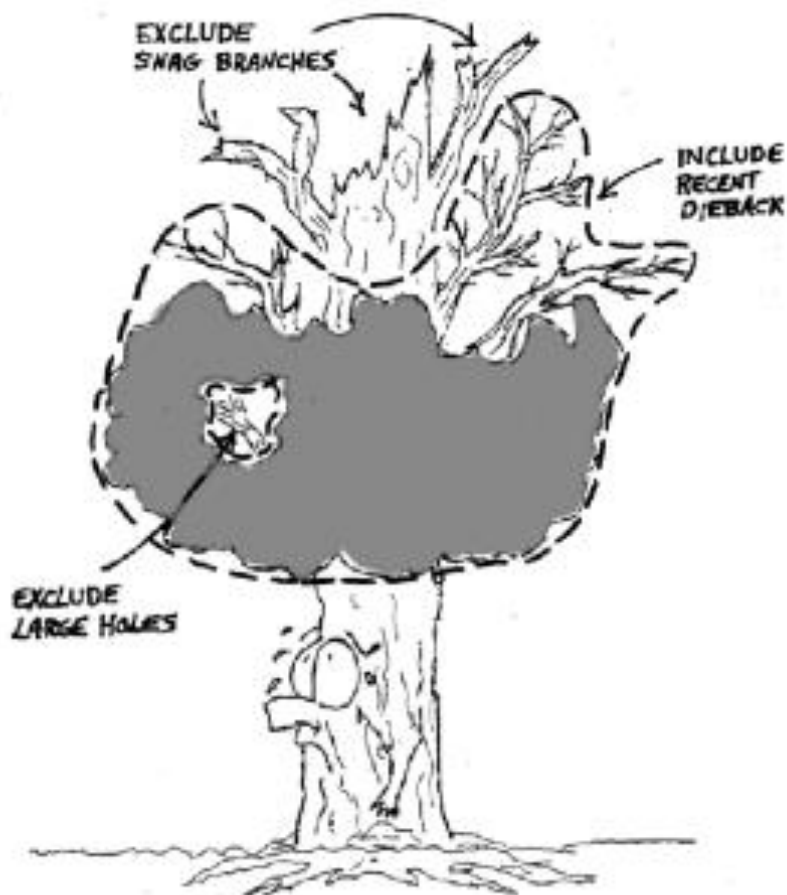
Figure 11. Dieback rating example (Randolph, 2010).

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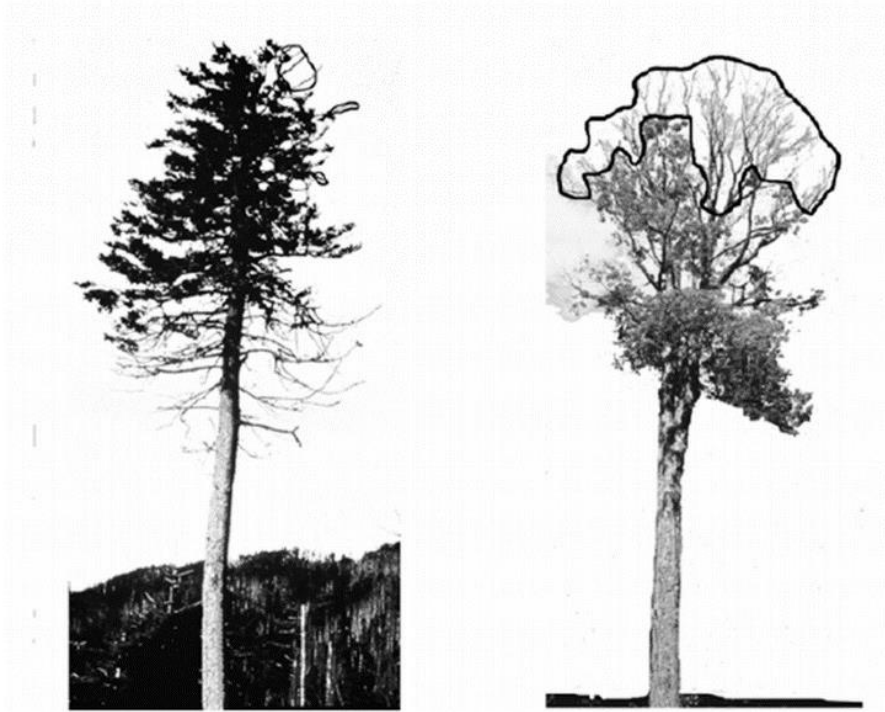
Figure 12. Crown dieback rating outline examples (Randolph, 2010). Dieback of left tree: 5%. Dieback of right tree: 30%.

Vigorous Crown

Dieback Obvious

Figure 13. Dieback comparison. Dieback of left tree: 5%. Dieback of right tree: 25%.

Foliage Transparency

Foliage size and density are valuable indicators of the current health of trees, and is measured using a visual estimate of foliage transparency. Foliage transparency is a rating of the amount of skylight visible through the live, normally foliated portion of the crown, excluding areas occupied by branches. This number is reported as the proportion of sky visible through live foliage as compared to full transmission of skylight (such that a rating of 5-10% means that only 5-10% of the total possible skylight is visible through the foliage).

To assist in the estimation of canopy transparency, a two-dimensional crown outline is projected around all living branches. The crown outline is determined and the transparency is estimated. Transparency is rounded up into 5% intervals (if a tree has 11-15% transparency, it is rated as a 15, if a tree has 16-20% transparency it is rated as a 20, etc). Two certified raters are required to make the transparency estimates from opposite sides of the tree.

Old trees and some hardwood species (e.g. sugar maples) have crowns with densely foliated branches that are naturally widely spaced. These large gaps between branches should not be included in the foliage transparency rating. When foliage transparency in one part of the crown differs from another part, an average foliage transparency is estimated.

It is important to check with binoculars to differentiate defoliated branches from dieback areas, as this assessment should only include live areas (including defoliatied areas) of the canopy. When defoliation is severe, branches alone will still screen much of the light, but the branches are excluded from the foliage outline. Rate the area as if the light was penetrating those branches. For example, an almost completely defoliated dense spruce may have less than 20 percent actual skylight showing through the crown, but it will be rated as highly transparent because of the missing foliage. A tree that is recently defoliated with only one or two leaves remaining would have a transparency rating of 99.

Different species have a normal range of foliage transparency based on their natural canopy structure. For example, a healthy yellow birch may have a transparency range between 10 and 25 while a white ash may be closer to 15 to 30 percent transparency.   However, ratings are not made in comparison to a normal tree, but rather based on what you see.

 (Adapted from Tallent-Halsell, 1994)
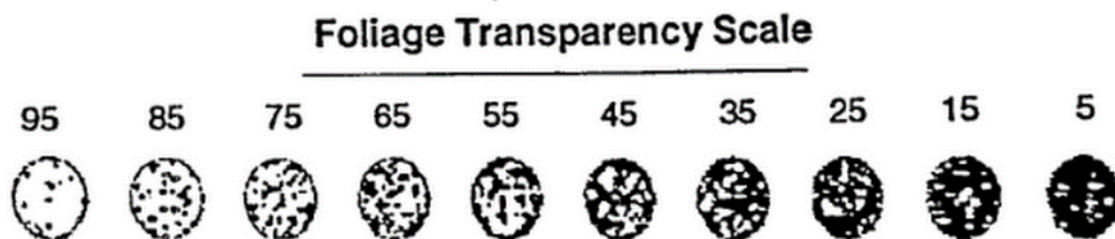
Figure 14 Foliage transparency scale (Tallent-Halsell, 1994).

Transparency 15% for both trees

Figure 15. Foliage transparency outline examples (Randolph, 2010).

Defoliation

Defoliation is an estimate of leaf area reduction caused by a disturbance factor. Defoliation results from insect outbreaks including pear thrips, gypsy moth caterpillars, forest tent caterpillars, etc, or from weather-related leaf damage such as frost or hail. It includes leaves with missing sections or in severe cases leaves with only veins remaining. Defoliation is estimated in four broad categories based on the total live crown that has reduced leaf area (see Table 3). Dieback is not included in this metric.

(Adapted from Millers et al., 1991)

Table 3. Defoliation classes and definitions.

Class	Definition
0	None to trace defoliation.
1	Less than 30 percent of crown defoliated.
2	31 to 60 percent defoliation.
3	More than 60 percent defoliation.

Figure 16. Defoliation on an American beech.

Foliage Discoloration

Foliage discoloration is estimated in four categories based on percentages similar to defoliation estimates (see Table 4). The percentage is based on the foliated portion of the crown that is discolored. Foliage is considered discolored when the overall appearance of a leaf is more yellow, red, or brown than green. When the observer is not sure whether the foliage is green, it is rated as green. When branches are dead but retain brown leaves or red needles, as with conifer flagging or broken branches, these are not included as discoloration. Two certified raters are required to make the discoloration estimates from opposite sides of the tree. Early leaf coloration likely resulting from stress agents is recorded in the notes.

(Adapted from Millers et al., 1991)

Table 4. Discoloration classes and definitions.

Class	Definition
0	None to trace discoloration.
1	Less than 30 percent of crown discolored.
2	31 to 60 percent discoloration.
3	More than 60 percent discoloration.

Figure 17. Example of foliage discoloration.
Source: USFS

Special Damages

In many cases, additional stress symptoms may be present. These provide useful information on the cause of decline reported for a given tree. Special damages are those often associated with tree declines, so not every pest or tree injury is recorded. They include damage agents in the following categories: animals, borers, insects, cankers, conks, diseases, human caused, and weather. Up to three damages for each tree may be recorded.

For special damage codes and descriptions, see Appendix E. Special Damages.

Figure 18. Beech bark disease symptoms, and example of special damages.

Additional Subplot-Level Metrics

Invasive Species

Non-native invasive plants are recorded on each subplot using a 5-class abundance system for each species on the invasive plant list (see Table 5). For photos of common invasive plant species to assist with identification, see Appendix E.

Table 5. Invasive plant species and abundance codes.

Species Code	Species Name	Latin Name
1	Barberry, Japanese and common	*Berberis thunbergii, B. vulgaris*
2	Buckthorn: common or glossy	*Rhamnus cathartica, R. frangula*
3	Bittersweet, oriental	*Celastrus orbiculatus*
4	Honeysuckle: Bell, Japanese, Amur, Morrow or Tartarian	*Lonicera X bella, L. japonica, L. maackii, L. morrowii, L. tatarica*
5	Multiflora Rose	*Rosa multiflora*
6	Norway Maple	*Acer platanoides*
7	Autumn or Russian Olive	*Elaeagnus umbellate, E. angustifolia*
8	Japanese knotweed	*Fallopia japonica (Polygonum cuspidatum)*
9	Garlic Mustard	*Alliaria petiolata (A. officinalis)*
10	Privet	*Ligustrum vulgare*
11	Tree of Heaven	*Ailanthus altissima*
12	Wild Chervil (cow parsnip)	*Anthriscus sylvestris*
13	Burning Bush or winged Euonymus	*Euonymus alatus*
14	Goutweed	*Aegopodium podagraria*
15	Amur Maple	*Acer ginnala*
99	Other (please specify)	

Invasive Plant Abundance Codes		
Abundance Code	**Description**	**Density**
1	Infrequent occurrence	1 to a few present
2	Sparsely throughout	1-2 plants together, in a few locations
3	Localized patches	Several plants together, occurring in a few locations
4	Frequent in stands	Dense areas of plants occurring in a few locations
5	Densely throughout	High populations making up understory and/or regeneration

Browse

Animal browse can alter growth and survival of tree regeneration. Record evidence of deer/moose browse on vegetation in each subplot as either Present (1) or Absent (0).

Moose browse on aspen. Photo credit: http://woodlandstewardship.org/wp-content/uploads/ch7/images/animal/moose_browse_damage_on_aspen_large.jpg

Deer browse. Photo credit: http://www.kellytreefarm.com/images/deer%20browse1.jpg

Basal Area

A 10 Basal Area Factor (BAF) wedge prism is used to measure basal area of trees at each subplot center. The prism is held over subplot center, and the number of trees of each species within the prism's variable radius plot is counted as the observer makes a 360-degree sweep around the plot. Trees determined to be 'in' are tallied by species and live/dead status, those that are 'borderline' are counted every other time, and those that are 'out' are discounted. Basal area is calculated by multiplying the number of counted trees by the Basal Area Factor of the prism used (i.e. 10).
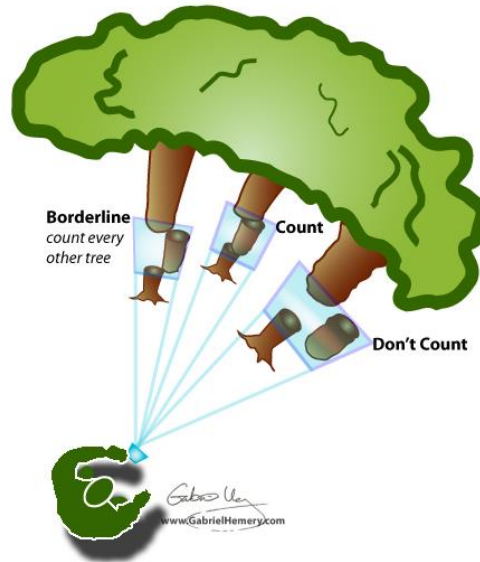
Figure 19. Examples of using a wedge prism. Photos courtesy of Gabriel Hemery, at www.GabrielHemery.com.

Microplot Measurements

Regeneration Measurements

It may be desirable to record measurements on the microplot before other subplot measurements to avoid any inadvertent trampling. Seedlings and saplings are recorded if the stem emerges from the ground within the radius of the microplot.

Seedlings

All established seedlings are tallied by species, excluding this year's germinants. This includes all established stems with a DBH less than 1 in (2.54 cm). Established hardwood seedlings will have leaves, not just cotyledons. On occasion, multiple seedlings are growing from the same root sprout. Each seedling is counted individually. Seedling species can be difficult to determine as leaf shapes can vary and differ from more mature plants. See Appendix F for photos and identification of common seedling species.

Two size classes are used to tally seedlings so they can be compared to past data. The 2 classes for conifers are: Class 1. less than 6 in. (15 cm) tall, and Class 2. 6 in. (15 cm) and less than 1 in. (2.54 cm) DBH. The 2 classes for hardwoods are: Class 1. Less than 12 in. (30 cm) tall and Class 2. 12 in. (30 cm) tall and less than 1 in. (2.54 cm) DBH.

Saplings

Saplings are greater than or equal to 1 in (2.54 cm) in diameter and less than 5 in. (12.7 cm) in diameter. We record the distance and azimuth from the microplot center to the sapling, the species, DBH, and status as living or dead. To avoid confusion with the trees on the larger subplot, sapling ID numbers start at 100, with the northernmost from the microplot center numbered first. The rest of the saplings are numbered clockwise from the first one. If an existing tallied sapling grows to 5 in. (12.7 cm) DBH, it is instead recorded as a tree, with a new distance and magnetic azimuth measured from subplot center. A sapling retains the same ID number when it moves to being a tree.

If a sapling is found to be dead two years in a row, it is removed from the sapling list.

(Adapted from Tallent-Halsell, 1994)

Ground Cover Measurements

Understory vegetation is recorded on each microplot as percent cover as viewed from above in 2-dimensions. Percent cover is recorded separately for: mosses, ferns, non-woody plants, shrubs, lichens, seedlings and bare ground. It is not expected that these will total 100% due to overlapping plant layers. Data are collected in 5% categories.

Photography Methods

Transparency Photos

The objective of taking digital photographs of each tree canopy is as a supplemental canopy transparency measure and as a visual record of canopy changes. The technique requires capturing as large an area of the canopy as possible in digital format for later quantification of light vs. dark pixels (i.e. percent canopy transparency). In contrast to tree foliage transparency methods described above, this is a simple assessment of light penetration through the canopy. To fully capture the whole canopy without including gaps or other tree crowns, it is best to zoom into a quadrant of the subject tree and take photos from four sides of the tree to ensure that as much of the canopy is captured as possible. Figure 20 and Figure 21 show examples of bad and good transparency photos, respectively.

Camera Set Up Instructions

a. Make sure that the flash is OFF

b. Turn date and time off to avoid text in the image

c. Turn auto review on so that you can immediately see if any of your pictures are bad (poorly lit, out of focus, containing large gaps) and need to be retaken

d) ISO is set to AUTO

e) Make sure that the camera lens is in the Manual position (M not AF) so that you can adjust zoom and focus manually.

Basic Transparency Photo Procedure

a) Start on the north side of the tree and continue around the tree at each of the cardinal directions going clockwise.

b) Standing with your back to the tree, zoom out and look up with the back of your head touching the trunk and the camera looking straight up.

c) Zoom in manually until as much of the canopy as possible is visible without any areas outside of the canopy in the picture at all (i.e. no sky visible outside of canopy). Note that many trees do not have perfectly circular canopies so you may have to zoom in or out in different amounts to ensure that you capture only the canopy of interest. In some cases, it is not possible to get a clear view of the canopy. These photos should be skipped to avoid including incorrect information.

d) Manually focus on the top of the canopy and adjust focus.

e) Adjust the aim of the camera so that the trunk at the top of the canopy (as it diminishes into nothing) is just visible at the top of the image. If this is not possible (because too much sky would be visible) it is OK to have more of the trunk in the image.

f) Write down the photo file number as recorded on the camera. Record any pertinent notes (such as if there were significant portions of other trees canopies in the photo, or if the maximum zoom wasn't enough to keep all gap out, or if the understory was so thick that is all you see, or if the tree was a leaner so there is lots of trunk in one picture and no canopy visible from the other side, etc).

Figure 20. Poor transparency photo - lots of sky, leaves from other trees in the frame.
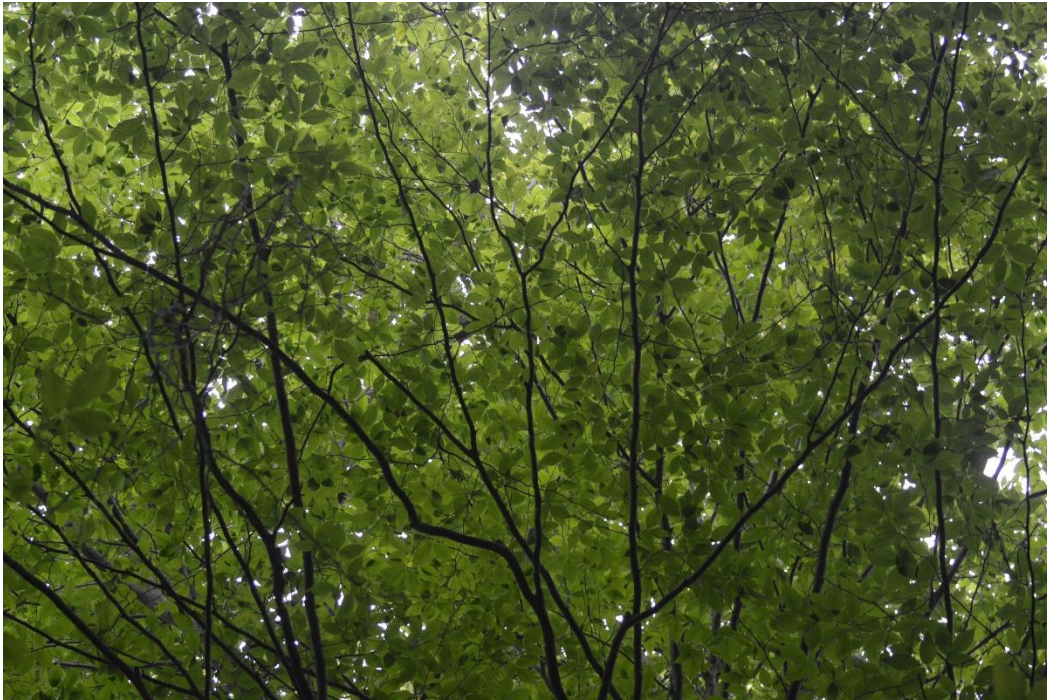
Figure 21. Good transparency photo - large amount of canopy, no large branches, no sky, no leaves from other trees.

Hemispherical Photos

The purpose of hemispherical photos is to get a detailed assessment of plot canopy structure that is repeatable from year to year. This requires photos taken at the exact same location, with the camera at the same height above ground, exactly level, and consistently with the top of the camera facing north. Figure 22 and Figure 23 show examples of poor and good hemispherical photos, respectively.

Materials: Digital camera with fisheye lens, tripod, tape measure, and compass.

Where to take photos: Directly over the center of the subplot (3 photos) and microplot (3 photos). Where possible, place center of tripod directly over subplot/microplot marking stake to ensure consistent photo location.

When to take photos: Lighting is best under cloudy conditions or early morning/late afternoon; try to avoid taking hemispherical photos with the sun shining directly overhead to avoid exposure issues.

Basic Hemispherical Photo Procedure

1. Ensure the camera is set to AUTO (FLASH OFF) mode for automated focus and ISO setting adjustments;

2. Attach the camera to the tripod and set the tripod over the subplot/microplot center;

3. Tip the camera all the way back so the lens is pointing upward;

4. If hemispherical photos have been taken at this plot before, adjust the height from ground to lens to match the height used in the previous visit. If this is the first time taking photos, set the height to approximately 3.28 ft (1 m) above the ground, and record the actual height to the top of the lens;

5. With the lens cap on, place a level on the lens and adjust the tripod until the camera is level;

6. Rotate the camera so the top of the camera faces magnetic north (0/360°) – ensure this by resting a compass on top of the lens cap and adjusting accordingly;

7. Ensure there are no obstructions to the canopy view (e.g. shrubbery, low-canopy understory trees, etc.). If the camera view is obstructed by low hanging vegetation, hold it out of the way of the camera. If it cannot be moved, do not take pictures at that location;

8. Make sure that you duck down so that other field members or equipment are not included in the field of view;

9. Hold the SHOOT button down halfway at first to ensure the camera is focused and then take 3 consecutive pictures;

10. Record the 3 unique picture IDs on the datasheet.

Figure 22. Poor hemispherical photo - sapling takes up most of the frame.

Figure 23. Good hemispherical photo - only the upper canopy is pictured.

Data Management

Field data collected on paper forms are entered into a MySQL database via a Microsoft Access front-end, and stored in the Forest Ecosystem Monitoring Cooperative's data holdings. Several data quality-control scripts are run to check for discrepancies in the current year data, as well as unexpected changes from previous years. In addition, all data in the database is documented using the Ecological Metadata Language standard (https://knb.ecoinformatics.org/#external//emlparser/docs/index.html), providing detailed information on the dataset as a whole as well as individual tables and attributes. Data are made publicly accessible within a year of input after quality-control and human assessment are undertaken. Project information and various datasets can be found at https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring.

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Jung, S. E., Kwak, D. A., Park, T., Lee, W. K., & Yoo, S. 2011. Estimating crown variables of individual trees using airborne and terrestrial laser scanners. Remote Sensing, 3:2346-2363.

Randolph, K. 2010. Phase 3 Field Guide - Crowns: Measurements and Sampling, Version 5.0. USDA Forest Service. http://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/2011/field_guide_p3_5-0_sec23_10_2010.pdf.

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Appendix A. Sample Data Sheets

Sample data sheets are included below

Date_____   Crew_____

Vermont Forest Health Monitoring - 2016 Subplot Data

PLOT: _____

SUBPLOT: _____

LATITUDE: _____

LONGITUDE: _____

CHECKLIST

DATA ENTRY

BROWSE
Present   Absent

NOTES

INVASIVES

Species	Abundance Code (1-5)

HEMISPHERICAL PHOTOS

Location	Lens Height (x.x m)	File Name

PRISM

Species	Live/Dead	Count

SEEDLING COUNTS

Species	Count

Date_____   Crew_____   Plot_____

Vermont Forest Health Monitoring - 2016 Subplot Data

SAPLINGS									
Sapling ID	**Azimuth**	**Distance (x.x m)**	**Species**	**Prev DBH (xx.x cm)**	**Prev Status**	**DBH (xx.x cm)**	**Dist Method (h,t)**	**Status**	**Notes**

Tree Stem Map

Not available

	Site
	Subplot number
	Tree number
	Azimuth (xxx)
	Distance (xx.x m)
	Species
	Prev. Trad. DBH (xx.x cm)
	Prev. Mod. DBH
	Prev. Height (xxx.x m)
	Prev. Crown class
	Prev. Vigor
	Traditional DBH (xx.x cm)
	Modified DBH (xx.x cm)
	Dendrometer DBH(xx.x cm)
	Crown class (1-5)
	Total tree height (m)
	Height to Live Top (m)
	Height to Crown Base (m)
	Ht meas method (v, c, h)
	Vigor rating
	Dieback (%)
	Transparency (%)
	Defoliation rating (0-3)
	Discoloration (0-3)
	Special damage 1 code
	Transp Photo File Names
	Notes

Date_____

Crew_____

Plot_____

Appendix B. Trimble GeoExplorer Field Data Collection Workflow

1. From initial start menu, click the Windows icon in top-left of screen and open **TerraSync**

    a. Initial screen will show the "**Skyplot**" under the **Status** options, which depicts satellite coverage

Initial Setup

2. Click on **Status** and navigate to the **Setup** options

    a. Under "**Coordinate System**" ensure you are collecting data with the following settings, then click OK:

        SYSTEM: **UTM**
        ZONE: **18 North**
        DATUM: **WGS 1984**
        ALTITUDE REFERENCE: **Height Above Ellipsoid (HAE)**
        ALTITUDE and COORDINATE UNITS: **Meters**

    b. Under "**GPS Settings**" ensure that the Productivity-Precision slider is set all the way to the Productivity end (left), then click OK – this tells the system to log data even when satellite reception is relatively poor and thus locational accuracy isn't very precise (can be fixed via post-processing)

    c. Under "**Units**" ensure the Lat/Long format is set to **DD.ddd°** (decimal degrees), then click OK

    d. Under "**Logging Settings**" ensure antenna height is set to 1.5 meters (**NOTE**: this is the height you want to be holding either the Trimble unit or external antenna at – see below – when logging locational data)

        i. If using the external antenna, ensure **Type** is set to "**Hurricane**" with **Part Number**: **50393-50**

        Ii. If using just the Trimble unit, ensure **Type** is set to "**GeoXH 2008 Internal**"

Creating a New Data File (Point) and Logging Location

3. Click on **Setup** and navigate to the **Data** options

    a. Ensure you're in the "**New**" tab and that the default settings show:

        File Type: Rover
        Location: Default
        Dictionary Name: Generic

b. Rename the **File Name** based on the plot you are at (e.g. VMC345-1 for subplot 1 in plot VMC345)

    c. Click **Create** in the upper-right of the screen

        A prompt will show the antenna **height** (1.5m) and **measure to** (bottom of receiver), click OK – **note the unit will assume these settings when logging locational data**

    d. Ensure the "**Point_generic**" option is highlighted, then click the **Create** button with the blue circle in the upper-right

    e. A **red target** now appears in the upper-right with a number next to it – this is the number of satellite "hits" the unit is logging at the point you've created

    f. Add any comments about the plot in the **Comment** box if needed

    g. **Let the unit log at least 100 points before clicking the OK button with the red stop square**

    h. Click Ok to confirm you want to close the feature: 1 Point_generic

    i. **Click Close in the upper right to ensure the data file is closed**

    j. You can check that you've successfully created the data file/point by clicking on the "**Existing File**" tab (still under the **Data** options)

    i. The data file you just created should be at the top of the file list, with the number of positions displayed in

the bottom right (e.g. **Positions: 103**). In the bottom left, it should say **Status**: **Not Transferred** as the file has not yet been downloaded from the unit.

k. If you made a mistake naming the file, or simply want to delete a file, you can click on the **File Manager** tab, then in the upper right click **Options**, **then Delete—NOTE:** be careful when deleting files that have not been transferred, as **they cannot be reclaimed**!

i. To rename a file click **Rename**

Shutting Down the Trimble

4. Once you've collected the point data and are ready to turn off the Trimble, **ensure that:**

    a. **The data file is closed**

    b. **That you've exited out of TerraSync**

Exporting from the Unit

NOTE: After connecting the Trimble unit to the computer via the USB cable, Windows Mobile Device Center must open before any data can be exported. This means that the computer has recognized the Trimble and thus GPS Pathfinder will too (Windows Mobile can be closed once you see it has recognized the unit). If Windows Mobile doesn't open, likely due to a driver installation failure, try unplugging the unit, turning it off, connecting the USB to the computer again, and then turning the unit back on.

1. The "**Select Project**" prompt will appear when GPS Pathfinder is opened – this is the database directory feature.

    a. In the "**Project Name**" drop-down menu, select "**FHM**". This project is linked to the TrimblePoints folder in the Forest Health Monitoring database.

        i. **Note:** If the FHM project does not appear, click "New" and link the Project Folder to the TrimblePoints folder (I:\ForestHealthMonitoring\Geodata\TrimblePoints), the "Backup files" to the Backup folder (I:\ForestHealthMonitoring\Geodata\Backup), and the "Export" and "Base" files to the TrimblePoints folder.

2. Before exporting data, click on the "**Options**" tab and select "**Coordinate System**". Ensure the GPS Pathfinder coordinate system is set to **WGS 1984** (Datum) **UTM** (System) **18 North** (Zone).

3. Click the "**Data Transfer**" button on the left-hand side of the Pathfinder window (second icon down with the computer-GPS unit symbol; you can also select it from the Utilities tab).

4. Ensure the "**Receive**" option is selected (it should read "Files to Receive" underneath), click "**Add**" on the right-hand side and select "**Data File**".

5. An "**Open**" screen will appear, and any data files on the Trimble that haven't been transferred to a computer will be highlighted. Ensure the files you want to transfer are the only files highlighted! Click "**Open**".

6. Back at the Data Transfer dialog box, click "**Transfer All**". This downloads the GPS data.

Data Correction

1. Click the "**Differential Correction**" button on the left-hand side of the Pathfinder window (third icon down with the circular-point symbol; you can also select it from the Utilities tab).

2. Add the uncorrected GPS files (.SSF) by clicking the big plus sign on the right-hand side of the Differential Correction Wizard dialog box, then click "Next".

3. Leave the default "**Processing Type**" (Automatic Carrier and Code Processing) and "**H-Star Processing**" (Use a single base provider).

4. Click "Select" Next to "**Base Provider Search**"

5. Before choosing a provider, click "**Update List**" on the right-hand side of the Select Base Provider dialog box. This refreshes the list of available base stations since Pathfinder was last used.

6. We want the **closest base station** with an **Integrity Index over 85**.
    a. To sort the provider list by **Distance** or **Integrity Index** (II), just click on the column heading.
    b. **IMPORTANT NOTE:** If there are no base stations with an II over 85 within 80 km (50 miles), use the Back button to navigate back to the "H-Star Processing" option and select "Use multiple base station providers".
        i. Keep the default options, and click "**Select**" next to Base Provider Group.
        ii. Click "**New**", give the group a name (e.g. "FHM"), and hit OK.
        iii. Click the big plus sign to add base providers, again filtering by **closest distance and highest II (above 85)**. **Choose 3 base stations.**

7. After selecting a base provider(s), click OK until you get to the "**Output Folder**" screen, keep the default options (Use the project folder and create a unique filename…).

8. Click **Start** and let it run. This generates the corrected GPS data.

Appendix C. Using the Haglof Hypsometer

Before sampling, the hypsometer should be checked for proper settings and re-calibrated:

To turn on the transponder: Place the receiver against the transponder, press and hold the DME button until you hear two beeps.

To turn off the transponder: Place the receiver against the transponder, press and hold the DME button until you hear four beeps.

To turn on for heights and calibration: Press and hold the orange **ON** button.

To turn on for measuring distance: Press the DME button while unit is off.

To turn off: Press and hold DME and IR buttons simultaneously.

Required Settings

Press the **IR** right arrow button to SETUP then press the **ON** button (works as an enter command) and make sure that units are

> **METRIC,**
> **TYPE 2,**
> **P Offset 0.2,**
> **T HEIGHT 1.3**
> **M DIST 0.0**

If any of these are not true use the arrow buttons to change settings up or down.

Calibration

Once setup is complete, hit the **IR** button again to get to the CALIBRATE option.

Pre-measure a distance of exactly 10m and have one person standing with the transponder at the far end. Aim the instrument at the transponder (when in Calibrate mode) and press on. The instrument will automatically shut off when complete.

Measuring Distance

With instrument turned off, press the "DME" button to access the distance function. Place transponder on object and point instrument at it from plot center. Press the DME button to measure the distance.

Measuring Heights

Put instrument in Height mode (see above). Place the transponder at breast height on the tree of interest where there is a clear line of site to both the transponder and top of the tree. Look through the viewfinder and center the red cross on the transponder. Press and hold the orange on button until you hear a beep. The red cross should begin blinking. Center the cross on the point you want to measure the height of, and press and hold the orange on button again until it beeps. You can measure up to three heights and they will be saved on the instrument display.

Appendix D. Common VT Tree Species Codes

Code	Species
12	balsam fir (Abies balsamea)
57	juniper; cedar (Juniperus)
68	eastern red cedar (Juniperus virginiana)
71	tamarack (Larix laricina)
90	spruce (Picea)
91	Norway spruce (Picea abies)
94	white spruce (Picea glauca)
95	black spruce; bog spruce (Picea mariana)
97	red spruce (Picea rubens)
105	Jack pine (Pinus banksiana)
125	red pine (Pinus resinosa)
126	pitch pine (Pinus rigida)
129	eastern white pine (Pinus strobus)
130	Scots pine (Pinus sylvestris)
241	arborvitae; northern white cedar (Thuja occidentalis)
261	eastern hemlock (Tsuga canadensis)
299	dead conifer species
310	maples (Acer)
313	ashleaf maple; boxelder (Acer negundo)
314	black sugar maple (Acer nigrum)
315	striped maple (Acer pensylvanicum)
316	red maple (Acer rubrum)
317	silver maple (Acer saccharinum)
318	sugar maple (Acer saccharum)
319	mountain maple (Acer spicatum)
351	red alder (Alnus rubra)
355	European alder (Alnus glutinosa)
356	serviceberry (Amelanchier)
370	birch (Betula)
371	yellow birch (Betula alleghaniensis)
372	sweet birch (Betula lenta)
375	paper birch (Betula papyrifera)
378	mountain paper birch (Betula cordifolia)
379	gray birch (Betula populifolia)

Code	Species
400	hickory (Carya)
402	bitternut hickory; pignut (Carya cordiformis)
407	shagbark hickory (Carya ovata)
531	American beech (Fagus grandifolia)
540	ash (Fraxinus)
541	white ash (Fraxinus americana)
543	black ash (Fraxinus nigra)
544	green ash (Fraxinus pennsylvanica)
600	walnut (Juglans)
601	butternut (Juglans cinerea)
602	black walnut (Juglans nigra)
660	apple (Malus)
701	eastern hophornbeam; hophornbeam (Ostrya virginiana)
740	cottonwood (Populus)
742	Eastern cottonwood (Populus deltoides)
743	bigtooth aspen (Populus grandidentata)
746	quaking aspen (Populus tremuloides)
761	pin cherry (Prunus pensylvanica)
762	black cherry (Prunus serotina)
766	American plum (Prunus americana)
800	oak (Quercus)
802	white oak (Quercus alba)
804	swamp white oak (Quercus bicolor)
823	bur oak (Quercus macrocarpa)
826	chinkapin oak (Quercus muehlenbergii)
832	chestnut oak (Quercus prinus)
833	northern red oak (Quercus rubra)
837	black oak (Quercus velutina)
901	black locust (Robinia pseudoacacia)
920	willow (Salix)
935	American mountain-ash (Sorbus americana)
951	American basswood (Tilia americana)
972	American elm (Ulmus americana)
975	slippery elm (Ulmus rubra)
998	unknown dead hardwood spp.

Appendix E. Special Damages

Special Damages Table

Bole Damage Code	Bole Damage Agent
Animal Damage	
441	Animal browse
444	Beaver damage
445	Porcupine damage
446	Sapsucker damage
447	Other animal damage
Borers and Insects	
707	Asian long-horned beetle
101	Balsam woolly adelgid
104	Beech bark scale only
111	Defoliation> 20%
103	Hemlock woolly adelgid
710	Sirex wood wasp
108	Sugar maple borer
110	Other bark beetles
711	Emerald ash borer
109	Other borers

Bole Damage Code	Bole Damage Agent
Cankers Conks and Diseases	
106	Beech bark disease symptoms
201	Butternut canker
206	European larch canker
203	Eutypella canker
204	Hypoxylon canker
202	Nectria canker
207	Other canker
208	Conks and other indicators of decay
209	Dwarf mistletoe
210	White pine blister rust
Human-related	
702	Logging damage > 20% of circumference
Weather-related	
708	Cracks and seams
501	Wind-thrown/uprooted
505	Other weather damage

Special Damages Supplement

Animal Damage

Animal Browse—441

Hosts: Any species bark & twigs

Description: Missing twigs, multiple stemmed regeneration; torn bark with teeth marks.

Porcupine damage– 445

Hosts: Bark and twigs of many species, notably eastern hemlock.

Description: Upper bole with bark missing and obvious feeding.

Beaver damage– 444

Hosts: Hardwoods found close to water.

Description: Lower bole with wedge-shaped feeding.

Sapsucker damage– 446

Hosts: Many species.

Description: Rows of small holes which can surround part of nearly all of tree stem.

Other animal damage– 447

Hosts: Any species.

Description: Bark removed from horn/antler rubbings.

Borers and Insects

Asian long horned beetle– 707

Hosts: Many hardwoods

Description: Bark scars at oviposition sites; circular exit holes; insect is large (ca. 1 inch), black with white spots, but no spot where thorax intersects wings, and long antennae.

Beech bark scale only– 104

Hosts: American beech

Description: Tiny insects with woollike wax covering often in bark cracks or other protected areas.

Balsam woolly adelgid– 101

Hosts: Balsam fir

Description: Damage symptoms includes gouting, swellings around buds and branch nodes. Insect is tiny, covered with white wool fibers, usually grouped at bark lenticels or around branch and twig nodes.

Defoliation > 20% - 111

Hosts: Any species.

Description: Feeding or loss of leaves or needles that affects more than 20% of the crown.

41

Hemlock woolly adelgid– 103

Hosts: Eastern hemlock.

Description: Small white fluffy masses covering wingless insects found at base of needles.

Sugar maple borer– 108

Hosts: Sugar maple

Description: insect bores diagonally below bark surface leaving a distinct line, but sometimes a sunken area with bark covering.

Sirex wood wasp– 710

Hosts: Pine species, commonly scots pine.

Description: Small exit holes especially on Scotts Pine boles.

Other bark beetles– 110

Hosts: Any species.

Description: Exit holes

Emerald ash borer– 711

Hosts: All ash species.

Description: Most obvious symptom is bark blonding, woodpecker activity resulting in bark removal. Small emerald colored beetle emerges from wood in early June.

Other borers– 109

Hosts: Any species.

Description: Symptoms include exit holes and galleries.

Beech bark disease symptoms– 106

Hosts: American beech.

Description: Diseased trees with craterlike scars.

European larch canker– 206

Hosts: All larch (tamarack) species.

Description: Bulging stem with black, resin exudate.

Butternut canker– 201

Hosts: Butternut.

Description: Sunken bark, oozing brown wounds with internal decay.

Eutypella canker– 203

Hosts: Maple species, including box elder.

Description: Ugly, irregular shaped bulge on bole with wood exposed in non-uniform pattern.

Hypoxylon canker– 204

Hosts: Quaking aspen and other poplars.

Description: Young cankers appear as sunken bark with yellowish-orange areas. Older cankers become blistered with blackened center.

Other canker– 207

Hosts: Any species.

Description: Obvious mycelium conks.

Nectria canker– 202

Hosts: Many hardwoods

Description: Target shaped open wound still actively expanding at outer rim.

Conks– 208

Hosts: Any species.

Description: Fruiting bodies indicating internal decay on the main bole or crownstem.

45

Dwarf mistletoe-209

Hosts: Primarily black spruce, occasionally other spruces and larch.

Description: Dense clustering of twigs or branches arising from a common point.

White pine blister rust– 210

Hosts: Pine species

Description: Symptoms vary with disease stage including red needled branch flag, depressed branch cankers with color contrast, and resin exudate from bole.

Logging damage > 20% of circumference– 702

Hosts: Any species.

Description: An opening or series of openings where bark has been removed exposing inner wood. Usually on lower bole, but

Cracks and seams– 708

Hosts: Any species.

Description: Vertical separations that break out to the surface often called frost cracks >5 feet in length. Seams develop as the tree attempts to heal.

Wind-thrown/uprooted– 501

Hosts: Any species. "Fir waves" common.

Description: Roots torn from ground along with trunk.

Appendix F. Invasive Species Identification Supplement and Codes

Japanese

Common

Barberry, Japanese and common—1

An armed deciduous shrub in the barberry family growing 8 to 10 feet in height and 6 feet in width. The bark is gray having sharp spines at nodes and the inner wood is yellow. Spines are double- or triple- branched. The arched hanging branches have clusters of leaves that are small, toothed, ovate, alternate, dull green above and grayish below.

Common

Glossy

Suzan Campbell, MNFI

© 2002 Gary Fewless
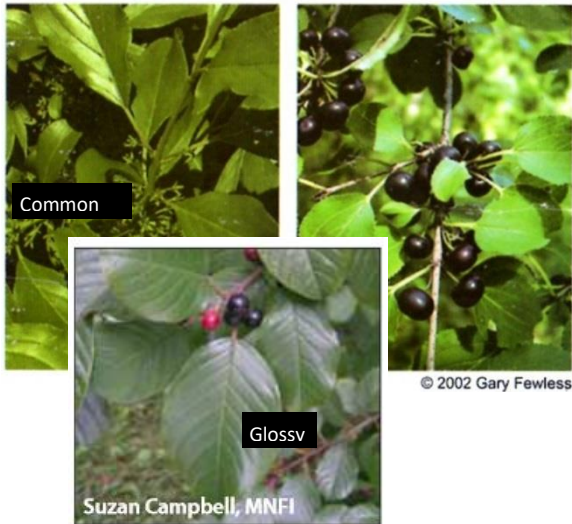
Buckthorn, common or glossy– 2

Deciduous woody shrub or small tree that ranges from 3 to 7.5 m (10-25 ft) in height. Leaves: Simple, dark green leaves, with toothed margins and 3 to 5 pairs of prominent leaf veins, which curve as they approach the leaf tip. The leaves are alternate, but some may appear opposite. twigs often have thorns at their tips, between the terminal buds.

UGA0016241

UGA2307125

Bittersweet, Oriental—3

Leafy, deciduous, sprawling, twining vine. Stems. Vines are many-branched, light brown to gray in color, may be green. Surface of smaller branches dotted with tiny, lighter-colored bumps (lenticels).
Leaves. Arranged alternately along the stem, leaves vary widely in shape and can be round, oblong or teardrop-shaped with finely toothed margins and tapering point.

Amur honeysuckle
(*Lonicara maackii*)

Japanese

Japanese Honeysuckle
(*Lonicera japonica*)

Tatarian honeysuckle
(*Lonicera tatarica*)

### Honeysuckle: Bell, Japanese, Amur, Morrow, Tartarian—4

Egg-shaped leaves range from 1 to 3 inches in length and are arranged oppositely along stems. Begin flowering May to June and bear small (< 1 inch), very fragrant tubular flowers creamy white to pink to crimson. L. morrowii and L. tatarica produce ¼ inch red berries from mid-summer through early-fall; L. maackii's dark-red berries don't ripen until late-fall; L. japonica produces dark-purple or black berries in the fall. Stems of all four are hollow.

Bill Johnson, James Miller (inset)

Multiflora Rose—5

Plant: multi-stemmed shrub, sometimes climbing vine, with arching stems and recurved thorns. Leaves: divided into five to eleven sharply toothed leaflets; leaf stalks with fringed stipules (paired wing-like structures). Flowers, fruits and seeds: clusters of showy, fragrant, white to pinkish, 1 in. wide flowers appear during May; small bright red fruits, or rose hips, develop during the summer and remain on the plant through the winter.
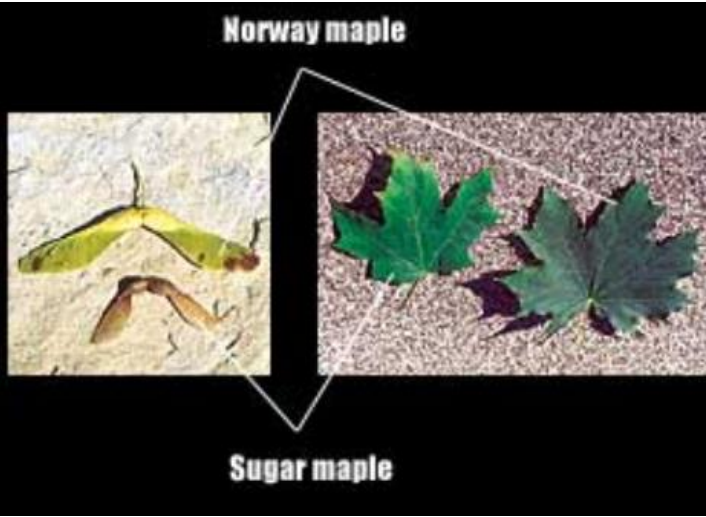
Norway maple

Sugar maple

Norway Maple—6

Large deciduous tree, dense canopy, 60' high when mature. Similar to native sugar maple except: broken leaf emits milky sap, upright green flower clusters, widely spreading winged fruit, regularly grooved bark, fall color always yellow. Leaves: Opposite, five lobed, coarsely toothed, pointed. Flowers: Flat-topped upright cluster, yellowish green, appearing with the leaves, blooming in May.

Russian Olive

Autumn Olive

UGA0016045

Autumn or Russian Olive—7

Russian Olive: Large deciduous shrub or small tree, up to 25' tall. Spreading branches form into a dense rounded crown. Thin bark comes off in narrow, elongate, fibrous strips. Twigs are very flexible and bear a terminal spine. Leaves: Alternate, distinctive silver-gray lance shaped. Flowers: Yellow spicy-fragrant flowers are borne either individually or in small clusters in the leaf axils, blooming in late spring.

Japanese Knotweed—8

Shrub-like, arching perennial herbaceous plant, over 10' high, reddish-brown stems, smooth, stout hollow and swollen at the joint where the leaf meets the stem. Leaves: Alternate broadly oval and pointed at the tip, about 6" long, 3 - 4" wide. Flowers: Greenish-white, branched clusters which grow from leaf axils, near the end of stems, blooming in late summer.

Garlic Mustard—9

Garlic odor produced when the leaves of the plant are crushed. Basal leaves of an immature plant dark-green, kidney shaped, round teeth along the edges; average size 6 to 10 cm in diameter. The petiole of first year plants are 1 to 5 cm long. In second year, alternating stem leaves become more triangular shaped, 1 to 5 cm long, sharper teeth. Leaf stalks of mature plants are hairy.

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L. japonicum L. lucidum L. sinense 'Variegatum'

Privet—10

Privets are evergreen shrubs that may reach 30 feet in height. These shrubs have opposite, leathery, oblong leaves that terminate with a pointed tip. The stems are opposite or whorled and red tinged with many raised lenticels and the bark is light gray. Many small, white, and fragrant flowers appear in April to June. Drupes containing 1 to 4 seeds mature from July to March.

UGA0016005

Tree of Heaven—11

Plant: deciduous tree reaching 70 ft. Twigs with smooth, pale gray bark, and twigs that are light chestnut brown, especially in the dormant season; leaves, stems and some flowers have a strong odor likened to cat urine or rotting peanuts or cashews. Leaves: alternate, large (1-4 ft. long), compound, with 11-25 smaller leaflets, each with one to several glandular teeth near the base. Flowers, fruits and seeds: large showy clusters of small yellowish-green flowers produced during June

Wild Chervil (cow parsnip) - 12

This is a biennial or short—lived perennial plant in the carrot family. It grows three to four feet on average but sometimes grows over six feet. Stems are hollow, branched and hairy. Fern-like leaves are nearly hairless and compound. Leaves form a basal rosette the first year. White flowers with five petals are produced in umbrella-like clusters that bloom from late May to early July during the plant's second

Burning Bush/Winged Euonymus—13

Deciduous shrub. Occasionally, four corky ridges appear along the length of young stems. Opposite, dark green leaves < 2 in long, smooth, rounded and tapered. Leaves turn bright crimson to purple in fall. Flowers inconspicuous, greenish yellow, 4 petals. Flowers develop in the spring and lay flat against the leaves. Fruit are reddish capsules that split to reveal orange fleshy seeds.

Goutweed—14

Most leaves basal, leafstalk attached to underground stem. Leaves divided into three groups of three leaflets. Leaflets toothed, sometimes irregularly lobed. "Wild" type foliage medium green; a commonly planted variegated form has bluish-green leaves with creamy white edges. Small, white, five-petaled flowers produced in mid-summer

Amur Maple—15

Amur maple is a small tree up to 20' high with a broad crown, but sometimes pruned as a hedge. Twigs are smooth and light colored. Leaves: Opposite, longer than wide and have three shallow lobes and double toothed edges, turning a brilliant red in fall. Flowers: Fragrant flowers appear in loose clusters with young leaves in May and June. Fruit: Numerous reddish, two-winged, inch long fruit mature in late summer.

Appendix G. Seedling Identification Supplement

Eastern Hemlock

Flattened needles that are soft and flexible, glossy green above and paler green below; 2 white lines on the underside along the midrib. Needles spiraled around shoot, but appearing two-ranked due to twisting of the petiole. Shorter, smaller needles than Balsam fir without the resinous, "Christmas tree" scent when crushed.

Similar Species: Balsam Fir

Balsam Fir

Flattened needles with white lines underneath, sessile (attached directly to stem) with disc-like appearance where needle meets stem. Longer, larger needles than hemlock, with distinct resinous "Christmas tree" scent when crushed. Needles spiral around shoot, though sometimes appearing two-ranked.

Similar species: Eastern Hemlock

Red Spruce

Roundish needles sharp and stiff to the touch, spirally arranged, appearing to spread in all directions. Reddish pubescence on the twigs, sometimes whitish pubescence when young. Raised, bumpy appearance where needles attach. Needles exude an orange rind odor when crushed. Generally found in upland/high elevation environments.

Similar Species: Black Spruce, White Spruce

Black Spruce

Roundish needles sharp and stiff to the touch, spirally arranged around shoot, appearing to spread in all directions. Dark rusty-greyish pubescence on the twigs. Shortest needles (0.5-1.5cm) of the spruces, appearing incurved. Needles exude a menthol odor when crushed. Grows in extremely wet, boggy habitat.

Similar Species: Red Spruce, White Spruce

White Spruce

Roundish needles sharp and stiff to the touch, spirally arranged around shoot, appearing crowded on upper side of branch due to twisting of bottom needles. Lacking pubescence on the twigs. Dark bluish-green needles that exude a disagreeable odor when crushed ("skunk spruce"). Grows in riparian and alluvial soils and edges of bogs.

Similar Species: Red Spruce, Black Spruce

White Pine

Needles bundled in clusters of 5, long (7-12cm), slender , straight, soft and flexible. **Red pine similar but with needles in bundles of 2 (not shown)**.

Similar Species: Red Pine (not shown—see above)

Sugar Maple

Simple, opposite leaves, usually 5-lobed but sometimes 3-lobed when young; lobes sparingly wavy-toothed with broad sinuses that are rounded at the base. Lobes lacking serrate margins exhibited by the similar species listed below.

Similar Species: Red Maple, Striped Maple, Mountain Maple

Red Maple

Simple, opposite leaves, usually 3-lobed but sometimes 5-lobed when young; lobes similar to Sugar Maple, but with many serrations around the margins. Leaves typically whitish and glabrous on the underside. Distinguished from Striped and Mountain Maple by deep sinuses similar to Sugar Maple.

Similar Species: Sugar Maple, Striped Maple, Mountain Maple

Striped Maple

Simple, opposite leaves, 3 shallow lobes above the middle that taper at the end. End lobe broadly triangular. Leaves finely and sharply doubly-serrate, usually with 3 prominent, palmate veins. Distinguished from Mountain Maple by tapering lobes and finer/double serrations on the leaf margins.

Similar Species: Sugar Maple, Red Maple, Mountain Maple

Mountain Maple

Simple, opposite leaves with 3 very shallow lobes. Leaves coarsely and irregularly serrate, larger teeth than Striped Maple. Soft, whitish pubescence on the underside of the leaf.

Similar Species: Sugar Maple, Red Maple, Striped Maple

American Beech

Simple, alternate leaves oblong and acuminate (tapering to a point) with coarse teeth regularly-spaced. Leaf veins terminate at each tooth on the leaf margin. American Elm is doubly-serrate with a rough leaf texture on the upper-side.

Similar Species: American Elm

Yellow Birch

Simple, alternate leaves oval , apex acuminate (tapering to a point) with coarse teeth regularly-spaced. Leaves sharply doubly-serrate with short petioles. Twigs and buds have a wintergreen flavor/odor when chewed/crushed. Often grow on decaying logs, stumps, and moss, also mineral-rich soil.

Similar Species: American Beech , Paper Birch

Paper Birch

Simple, alternate leaves ovate or triangular with coarse, doubly-serrate teeth. Rounded, entire leaf base. Very shade intolerant, typically growing in open, disturbed areas and large canopy gaps. Lacking wintergreen odor/taste of Yellow Birch.

Similar Species: Yellow Birch

American Elm

Simple, alternate leaves obovate-oblong with coarse doubly-serrate teeth that appear as a smaller tooth on top of a larger one. Often rough to the touch on the upper-side of the leaf, thick and firm. Leaf base is asymmetrical, though this may be harder to notice on very young seedlings.

Similar Species: American Beech

Black Cherry

Simple, alternate leaves narrowly oval to oblong-lanceolate or acuminate. Dark green and lustrous/shiny on upper-side of leaf, paler beneath with dense, reddish-brown pubescence along both sides of the midrib near the blade base. Finely serrate with incurved teeth. Petioles with small red glands near the blade base. Pin Cherry lacks the pubescence along the midrib.

Similar Species: Pin Cherry (not shown)

White Ash

Pinnately compound, opposite leaves usually 7-9 per leaflet. Leaves entire or obscurely serrate near tip, usually with small bumps on the underside (papillose). Stout, grooved petioles.

Similar Species: Mountain Ash , Shagbark Hickory

Mountain Ash

Pinnately compound, alternate leaves usually 9-17 per leaflet, 3-4x as long as broad. Leaves sessile or nearly so except for the terminal leaf, finely or sharply serrate above the entire base. Stout, grooved petioles.

Similar Species: White Ash, Shagbark Hickory

Shagbark Hickory

Pinnately compound, alternate leaves almost always 5 per leaflet, terminal leaf almost always larger than the lateral. Leaves finely serrate and fringed with minute, dense tufts of white hair upon most of the serrations in full sunlight. Fragrant when crushed.

Similar Species: White Ash, Mountain Ash

Basswood

Simple, alternate, heart-shaped leaves, typically with uneven base. Seedlings exhibit unique palmately-lobed cotyledons. This feature distinguishes Basswood from Hobblebush (not shown). Hobblebush also has opposite leaves in pairs, with rust-colored hairs on the undersides and prominent veins.

Similar Species: Hobblebush (not shown—see above)

Quaking Aspen

Simple, alternate leaves, broadly ovate to nearly round, dark green and lustrous (shiny) above, paler below. Long petiole, often longer than the leaf, that is flattened so that the leaves appear to quake/tremble in the slightest breeze. Finely serrate with somewhat rounded teeth.

Similar Species: Bigtooth Aspen (Not shown)

Red Oak

Simple, alternate leaves, 5-11 lobed with coarse-toothed, bristle-tipped lobes tapering from broad bases and round, oblique, rounded sinuses. Younger leaves without deep sinuses, but still coarsely-toothed and bristle-tipped. Typically dull green on the upper-side, seedlings turning red in fall.

Similar Species: Black Oak (Not shown), White Oak (Not shown)

Appendix H: Metadata and Database Structure

The VMC Forest Health Monitoring data is stored in a relational MySQL database. The diagram is shown in Figure 25.
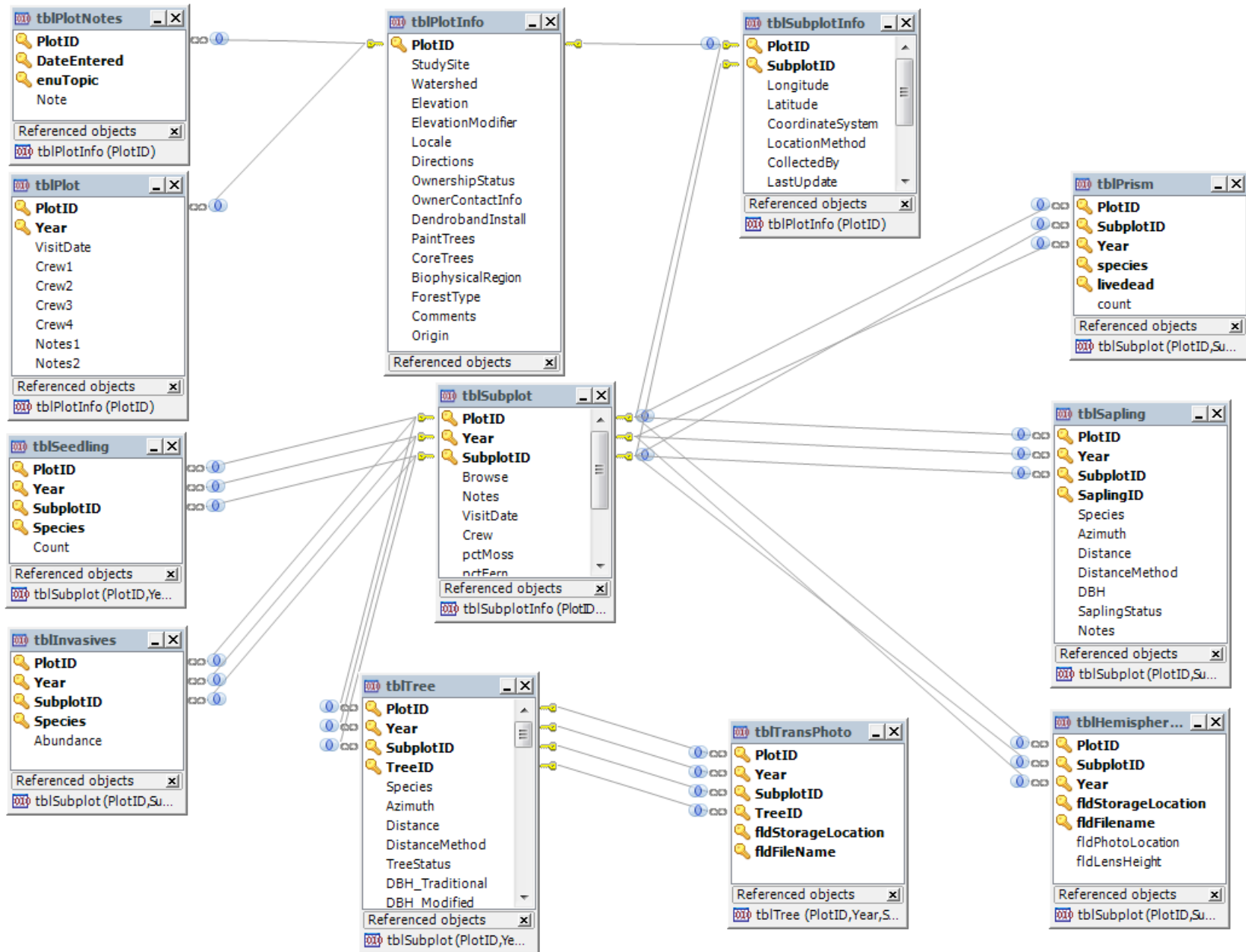
Figure 24. Schematic overview of the VMC FHM database and table relationships

Plot Identifying Information Table (tblPlotInfo)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/plot-identifying-information/overview#fields

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
PlotID	Plot identification	Unique plot identifier	varchar	nominal		
StudySite	Study Site	Study site where plot is located	varchar	nominal		
Watershed	Watershed	Watershed location of plot	varchar	nominal		
Elevation	Elevation	Average elevation of plot	int	ratio	Meter	
ElevationModifier	Elevation Modifier	Category used to create unique plot identifier	varchar	nominal		
Locale	Locale	General area plot is located in	varchar	nominal		
Directions	Directions	Directions to plot	varchar	nominal		
OwnershipStatus	Ownership Status	Ownership status, public or private	varchar	nominal		
OwnerContactInfo	Owner contact Information	Contact information to reach owner	varchar	nominal		
DendrobandInstall	Dendroband Install	Permission status for dendroband install	varchar	nominal		
PaintTrees	Paint Trees	Permission status for painting trees	varchar	nominal		
CoreTrees	Core Trees	Whether tree coring occurred on plot				
BiophysicalRegion	Biophysical Region	Biophysical region in which plot is located	varchar	nominal		
ForestType	Forest Type	Type of forest cover	varchar	nominal		
Comments	Comments	Observer notes	varchar	nominal		
Origin	Origin of Plot	Monitoring program that established plot	varchar	nominal		

Subplot Identifying Information Table (tblSubplotInfo)

TBC (#432)

Plot Visitation Table (tblPlot)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/plot-visitation-information/metadata#fields

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
PlotID	Plot Identification	Unique plot identifier	varchar	nominal		
Year	Year	Year of data collection	datetime	dateTime		YYYY
VisitDate	Visit Date	Date of plot visit	datetime	dateTime		YYYY-MM-DD
Crew1	Crew 1	Name of first crew member	varchar	nominal		
Crew2	Crew 2	Name of second crew member	varchar	nominal		
Crew3	Crew 3	Name of third crew member	varchar	nominal		
Crew4	Crew 4	Name of fourth crew member	varchar	nominal		
Notes1	Notes 1	Field note entry 1	varchar	nominal		
Notes2	Notes 2	Field note entry 2	varchar	nominal		

Subplot Visitation Information Table (tblSubplot)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/subplot-visitation-information/metadata#fields

TBC (#431)

Prism Measurements on Subplots Table (tblPrism)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/prism-measurements-on-subplots/metadata#fields

#428

Invasive Species Observation Table (tblInvasives)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/invasive-species-observations/metadata#fields

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
PlotID	Plot Identification	Unique plot identifier	varchar	nominal		
Year	Year	Year of data collection	datetime	dateTime		YYYY
Subplot	Subplot identification	Unique subplot identifier	int	nominal		
Species	Species Code	Numeric code assigned to invasive species	int	nominal		
Abundance	Abundance Code	Numeric code representing abundance of invasive species	int	ordinal		

Hemispherical Photo Identifying Information Table (tblHemisphericalPhoto)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/hemispherical-photo-identifying-information/metadata#fields

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
PlotID	Plot Identification	Unique plot identifier	varchar	nominal		
SubplotID	Subplot Identification	Unique subplot identifier	int	nominal		
Year	Year	Year of data collection	datetime	dateTime		YYYY
fldStorageLocation	Field Storage Location	Location of data storage	varchar	nominal		
fldFilename	Field File Name	File name of hemispherical photo	varchar	nominal		
fldPhotoLocation	Field Photo Location	Location where hemispherical photo was taken	varchar	nominal		

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
fldLensHeight	Field Lens Height	Height at which hemispherical photo was taken	double	ratio	meter	

Sapling Measurements on Subplots Table (tblSapling)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/sapling-measurements-on-subplots/metadata#fields

TBC #429

Seedling Measurements on Subplots Table (tblSeedling)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/seedling-measurements-on-subplots/metadata#fields

TBC #430

Transparency Photo Identifying Information (tblTransPhoto)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/transparency-photo-identifying-information/metadata#fields

TBC #433

Tree Health and Physiology Measurements Table (tblTree)

Metadata online at: https://www.uvm.edu/femc/data/archive/project/forest-health-monitoring/dataset/tree-health-and-physiology-measurements/metadata#fields

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
PlotID	Plot Identification	Unique plot identifier	varchar	nominal		
Year	Year	Year of data collection	datetime	dateTime		YYYY

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
SubplotID	Subplot identification	Unique subplot identifier	int	nominal		
TreeID	Tree Identification	Unique tree identification number	int	nominal		
Species	Species Code	Species code	varchar	nominal		
Azimuth	Azimuth	Azimuth from point center to tree (magnetic north)	int	interval	Degrees	
Distance	Horizontal Distance from Center Point	Horizontal distance from center point to tree	double	ratio	Meters	
DistanceMethod	Distance Measurement Method	The method used to measure distances - tape or hypsometer	varchar	nominal		
TreeStatus	Tree Status Code	Coded tree status	int	nominal		
DBH_Traditional	Diameter at Breast Height	Diameter at breast height using traditional method	double	ratio	Centimeters	
DBH_Modified	Diameter at Breast Height Modified	Diameter at breast height measured at painted band on tree ensuring same location for future measurement	double	ratio	Centimeters	
DBH_Dendroband	Diameter at Breast Height Dendroband	Diameter at breast height using a dendroband installed on tree	double	ratio	Centimeters	
CrownClass	Crown Class	Position of the crown relative to neighboring trees	int	ordinal		
TotalLength	Total Length	Tree height including dead or broken top	double	ratio	Meters	
ActualLength	Actual Length	Tree height to top of live crown	double	ratio	Meters	
CrownBaseHeight	Crown Base Height	Height from ground to base of tree crown	double	ratio	Meters	

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
HeightMethod	Height Measurement Method	The method used to measure heights - visual, clinometer, hypsometer	varchar	nominal		
Vigor	Tree Vigor Code	Coded tree vigor rating	int	ordinal		
Dieback	Crown Dieback	Code representing the percentage of the live crown area including the dieback area	int	ordinal		
Transparency	Crown Transparency	Foliage transparency indicator class	int	ordinal		
Defoliation	Defoliation Class	Crown defoliation class	int	ordinal		
SpecialDamage1	Special damage 1	Code for special damage 1 (code undefined)	int	nominal		
Discoloration	Discoloration Code	Code for discoloration class	int	ordinal		
Notes	Notes (observations/clarifications)	Notes by text or special damage code	varchar	nominal		
UncompactedCrownRatio	Uncompacted Crown Ratio	Live crown ratio is the percentage of total tree height supporting live foliage that is contributing	int	ordinal		
SaplingVigor	Sampling Vigor	Coded sapling vigor rating	int	ordinal		
CrownDensity	Crown Density	Average of crown density indicator for each plot (%)	int	ordinal		
LocationofDamage1	Location of Damage 1	Code for location of damage 1	int	nominal		
Damage1	Damage 1	Code for damage 1	int	nominal		
SeverityofDamage1	Severity of Damage 1	Code (0-9) for severity of damage 1	int	ordinal		
LocationofDamage2	Location of Damage 2	Code for location of damage 2	int	nominal		
Damage2	Damage 2	Code for damage 2	int	nominal		

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
SeverityofDamage2	Severity of Damage 2	Code for severity of damage 2	int	ordinal		
LocationofDamage3	Location of Damage 3	Code for location of damage 3	int	nominal		
Damage3	Damage 3	Code for damage 3	int	nominal		
SeverityofDamage3	Severity of Damage 3	Code for severity of damage 3	int	ordinal		
CauseofDeath	Cause of Death	Code for cause of tree death	int	nominal		
Counter	Counter	Record counter	int	ordinal		
TreeOrientation	Tree Orientation	Order of trees on each plot for use in data collection	int	interval		
LeanAngle	Lean Angle	Lean angle code	int	nominal		
LengthMethod	Length Method	Length method code	int	ordinal		
pctRottenMissing	Percent Rotten / Missing	Percent class volume of missing or rotten	int	ordinal		
DecayClass	Decay Class	Coded decay class	int	ordinal		
CompactedCrownRatio	Compacted Crown Ratio	Portion of tree supporting live foliage as a percent of actual tree height	int	ordinal		
CrownExposure	Crown Exposure	Crown exposure class	int	ordinal		
CrownLight	Crown Light	Crown light class	int	ordinal		
CrownPosition	Crown Position	Crown position relative to forest canopy	int	ordinal		
TreeHistory	Tree History	Tree history code	int	nominal		
CrownDensity1992	Crown Density 1992 and Beyond	Crown density changed from plot average to individual tree coded density rating	int	interval		
CrownDiameter1	Crown Diameter at 90 degrees	Crown diameter at 90 degrees from first measure	int	ratio		

Name in Database	Attribute Name	Description	Data Type	Measurement Type	Unit (if applicable)	Date/Time Format (if applicable)
CrownDiameter2	Crown Diameter at Widest Side	Crown diameter at widest side	int	ratio		
CauseofDamage1	Cause of Damage 1	Coded number for cause of damage 1	int	nominal		
CauseofDamage2	Cause of Damage 2	Coded number for cause of damage 2	int	nominal		
CauseofDamage3	Cause of Damage 3	Coded number for cause of damage 3	int	nominal		
TreeHeight	Tree Height	Tree height	int	ratio		
PreviousDBH	Previous Diameter Breast Height	Previous collection of diameter at breast height	double	ratio		
DiamChk	Diameter Check	Code for measurement accuracy	int	nominal		
SpecialDamage2	Special Damage 2	Code for special damage 2 (code undefined)	int	nominal		
SpecialDamage3	Special Damage 3	Code for special damage 3 (code undefined)	int	nominal		
Aspect	Aspect	Direction plot faces	varchar	nominal		